REFLECTIONS

ON

INLAND NAVIGATIONS:

AND A

NEW METHOD propoſed for executing the intended NAVIGATION betwixt the FORTH and the CLYDE, in a compleat Manner, at an Expence a Third leſs than what that Work has hitherto been eſtimated at.

The ſame Method applied to almoſt all Rivers and Rivulets, by which GREAT BRITAIN and IRELAND might have, at a very eaſy Expence, above 5,000 Miles of New Inland Navigations.

Tœdet quotidianarum harum formarum. TER.

LONDON:

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30
DEC

TO THE

NOBLEMEN AND GENTLEMEN

SUBSCRIBERS,

FOR FORMING A

NAVIGABLE CANAL

TO JOIN THE

FORTH and CLYDE,

The following DISCOURSE, compoſed at their Deſire,

is moſt humbly addreſſed,

by their moſt Obedient Servant,

LONDON,
Jan. 10. 1768.

J. GRAY.

25


30
DEC

REFLECTIONS

ON

INLAND NAVIGATIONS, &c.

IT muſt give a ſingular pleaſure to every well-wiſher to Great Britain, to ſee ſo much attention at preſent beſtowed upon the forming of Navigable Canals in different parts of this iſland, particularly, in regard to that for opening a communication for ſea-veſſels betwixt the Forth and Clyde, which, though not the moſt difficult in point of execution, is by far the moſt national, and moſt important. This, as it is now propoſed to be executed by the ſubſcribers, will not partially regard the benefit of a ſingle town, or extend its influences to one or two counties only, but will be a thoroughfare for the eaſt and weſt coaſts of the whole iſland, nay even for different nations; for it will, in a manner, bring Ireland and America on the one hand, and Germany and the nations of the Baltic on the other, reciprocally 300 miles nearer each other. Foreigners will therefore doubtleſs be ſurpriſed to find this an attempt of private undertakers, when

when the very nature of it renders it a national object of the firſt importance. Such, I make no doubt, but it will appear to our legiſlature; and that, if private funds ſhould fail, or prove inſufficient, we may expect to ſee it carried on and compleated at the public expence with the general approbation. What therefore, I think, ought chiefly to be attended to at preſent, is the manner of doing it well, and to the beſt advantage, without a ſtrict limitation as to the expence. But though no certain ſum ſhould now be fixed upon for the finiſhing of the undertaking, it is nevertheleſs extremely proper to examine how the leaſt expence may be incurred in executing the work in the compleateſt manner.

Mr. Smeaton has, with much ſolidity and diſcernment, given a diſtinct and accurate detail of the requiſites for compleating a Navigation, upon the ſuppoſition of digging an artificial Canal from ſea to ſea; and if that plan ſhould be adopted, I am perſuaded, that the real expence would be found to differ extremely little from his eſtimates. I propoſe, however, to offer another method, which appears to me to be much more natural, much more ſimple, to be founded on the plaineſt principles of hydroſtatics, and which would anſwer every purpoſe of the ſubſcribers, in affording an eaſy and ſafe Navigation for ſea-veſſels from frith to frith, though it would coſt conſiderably leſs than the plan hitherto propoſed.

When

When water is confined on every ſide, it naturally places itſelf upon a level; but if any one part of the confining bank be made lower than the ſurface, the water will immediately deſcend by that breach till it meets with ſome other obſtacle; for its gravitation makes it always ſeek to approach the center of the earth, and its fluidity gives it an eaſy opportunity of eſcaping; for a declivity in one part affects the whole ſurface. Let us ſuppoſe a quantity of water, of an equal depth, contained in an oblong veſſel, with two ſides and two ends, the ſides and ends will have an equal preſſure upon them; and were the breadth and length to be augmented never ſo much, yet if the depth be not augmented, the preſſure upon the ſides and ends is no more in the greater ſurface than in the ſmaller; for it is an eſtabliſhed principle, that water does not preſs againſt its banks according to its ſurface, but according to its perpendicular heighth or depth. A Canal or a river made navigable by art, is nothing elſe between lock and lock than this oblong veſſel, and the ſame banks that will contain a ſmall millſtream ten feet broad, will ſuffice to contain a Canal 100 feet broad, if the depth in both be equal; and ſhould an overflowing happen, it is altogether indifferent whether the ſuperabundant water eſcape by the ſides or by the end; nay, by the conſtruction which I ſhall propoſe, its eſcaping by the end is attended with particular advantages. I think therefore, that in numberleſs caſes, it may be deemed labour thrown

away

away to carry Canals along the ſides of rivers at a great expence of digging, extra-banking, Aqueduct-Bridges, Tunnels, Sluices, *&c.* when often at a leſs expence, and to a much better effect, the rivers themſelves might be made navigable, without the leaſt cauſe of apprehenſion of any exceſs of water, as in the very conſtruction of the Canal the danger of an overflowing may be provided againſt. The great rapidity and violence of rivers during a flood, has no doubt been the reaſon that deterred the conſtructors of Canals from riſking any communication with them. But though a body of water running down a declivity be a furious giant overturning every thing before him, yet, if this ſaid giant be laid flat upon his back, he loſes all his force, and becomes entirely paſſive, whatever be his ſize. If they had reflected on this principle, they might have eaſily ſeen, that they had it in their power, by banks and dams of a particular conſtruction, to bring almoſt every river requiring art to render it navigable to this paſſive ſtate; I ſay almoſt every river, becauſe direct cataracts, and perpendicular waterfalls muſt be excepted. Some other rivers alſo, conſiſting of a large body of water running down a ſteep deſcent, ought to be neglected, becauſe it could hardly be expected, that the profit ariſing from the Navigation could repay the expence of making it.

But that is far from being the caſe with the two ſmall rivulets that have their courſe in the tract of

the intended Navigation. They are both very inconſiderable, are almoſt dry in ſummer, and run very gently to the different ſeas, excepting in one place, where one of them has a cataract, which may be eaſily avoided. The reader, who has not an opportunity of viewing the tract upon the ſpot, may imagine to himſelf a narrow valley running tranſverſly for thirty miles from ſea to ſea, and bounded on the ſouth and north by high and mountainous ground. The middle of this valley is almoſt a dead level for about ten miles; and two ſmall brooks that riſe there form a ſtrait line by running in oppoſite directions into different ſeas. The current of thoſe brooks is extremely gentle; for the place where they take their riſe has been found by meaſurement, not to be more than 147 feet above the level of the ſea, an idea of which deſcent may be conceived, by ſuppoſing a rope faſtened to the top of a ſteeple 147 feet high, and extended about nine miles before it reaches the ground.

From this account it plainly appears, that the queſtion ought not to be about the digging of an artificial Canal, but about the banking in of two ſmall brooks. So far from being afraid of thoſe two rivulets, I actually conſider them as nothing; but regard their channel as the moſt proper bed and declivity for the Canal, a declivity pointed out by nature, which may eaſily be reduced to ſo many levels by dams and locks, and which may be banked in on both ſides at what breadth we pleaſe, without

having any extra digging, or extra banking in their whole courſe, but on the contrary, offering us great part of the work already done to our hands. Theſe rivulets, in their courſe, keep always in the lowermoſt part of the valley; and in carrying a Canal through this valley, is it not moſt natural to take the holloweſt part for the courſe of the Canal, rather than carry it over waving and irregular ground, which by being too high in ſome parts, occaſions extraordinary digging, and by being too low in others, requires extraordinary banking? By chuſing the courſe of the rivulets for the tract of the Canal, ſluices, tunnels, and aqueduct bridges are alſo all ſuperſeded, and rendered unneceſſary; for inſtead of our turning aſide little rivulets or occaſional ſtreams, the Canal would be the common receptacle of all of them, as it would be ſo ſituated as to receive them all; and by its conſtruction, could never be incommoded by them. The following this tract would likewiſe be attended with other advantages, particularly, there would be no new ſeparation and diviſion of private property, and there would be very little occaſion at all for any change of property, excepting of the property of the rivers and their banks; for though the rivulets are inconſiderable, yet in many places there is as much land waſted on both ſides of them, as would ſuffice for ground for the Canal were it even to be 100 feet broad; and ſurely that waſte ground cannot be highly valued by the preſent proprietors. By placing the Canal in the hollow, it would alſo be

eaſier to improve the ground on both ſides of it, which will no doubt ſoon change its face after the Navigation is finiſhed, and become three or four times more valuable than it is at preſent. But what is the moſt material of all is, that this tract ſeems by nature moſt fitted for the courſe of the Canal.

As the two rivulets that run through this valley are inconſiderable, in proportion to the intended ſize of the Canal, and, as ſhall be afterwards ſhewn, can never be dangerous even in floods, I would propoſe that the hollow of the valley where they run ſhould be fixed upon for the courſe of the Navigation; and I would form the Canal, not by digging for the whole depth, but by two parallel mounds or banks placed 80 feet aſunder the whole way, even at the locks, like two parallel turnpike roads, and raiſed ſo high, that the banking and digging put together ſhould include a depth of 12 feet. In forming the Canal by banking along the courſe of the rivulets, we ſhould have, as I ſaid above, great part of the work already done to our hands; for the rivulets, in many places, have formed a conſiderable channel, which they rarely occupy; in others their ordinary ſurface is one, two, or more feet below the banks, and in others, the ground cloſe by the river naturally forms a conſiderable mound, ſo that the water might there be kept up 12 feet deep by one artificial bank only. All theſe natural advantages are ſo conſiderable, that I am perſuaded

they would render the expence of forming the banks one third leſs than it would otherwiſe be.

Let us conſider the Canal a while, as extending from ſea to ſea without locks, and the two banks ſloping in the proportion of five to three, it affords us a capacious bed 12 feet deep, 48 feet broad at bottom, and 80 feet broad at top. This gives us a medium breadth of 64 feet, which multiplied by 12 feet, the greateſt depth, gives 768 feet for the contents of the Canal. Let us now compare this with the two rivulets both in their common ſtate, and in their greateſt augmented ſtate, and we ſhall find that even in the laſt, they would be entirely abſorbed in the Canal, and would never overtop its banks. In the end of November laſt, when there was a great deal of water on the ground almoſt every where, I viewed both the Bonie Water and the Kelvin, which were then each of them in an augmented ſtate, and, as I was aſſured, near double their ordinary ſize; yet even then the Bonie Water near Bonie Bridge was only about 10 feet broad and one foot deep; and the Kelvin at Inchbelly Bridge was about 15 feet broad, and a foot and an half deep, which gives for the medium quantity of water a little more than 16 feet, when the rivers were double their ordinary ſize. The quantity then flowing in their ordinary ſtate is only about eight feet, which is not the hundred and fiftieth part of what might flow in a Canal of the dimenſions abovementioned, upon the ſuppoſition of its being brimful,

brimful, and the current meeting with no ſtop or obſtruction from ſea to ſea. It may however be ſaid, that though the rivers Bonie and Kelvin be really very inconſiderable in dry weather, yet there is ſeldom a winter paſſes that they are not ſwoln with land floods, which raiſe them above their banks, and overflow the country for ſeveral hundred yards on both ſides. But let theſe floods be narrowly examined into, and the greateſt exceſs of them computed, by conſulting the oldeſt perſons living in the neighbourhood, and I am perſuaded it will be found, that they never have riſen to ſuch a degree as that they could not be contained with eaſe in the channel of the propoſed Canal.

There was this very autumn a great flood in the Kelvin, which overflowed the vale in many parts, for a length of five or ſix miles, and carried off conſiderable quantities of corn that was ſtanding in ſheaves upon the fields; and ſo great a flood, I believe, has not happened for very many years paſt. Yet I have been aſſured, that by marks upon ſome trees and ſhrubs near Inchbelly Bridge, it appeared this great flood had not riſen more than ſix feet above the uſual level of the river. Its ſpreading wide over the vale was only a proof of the levelneſs of the vale, and was owing to its not being confined; for, excluſive of 30 or perhaps 40 feet in the middle, where lay the thread of the ſtream, all that great breadth was dead water, which, if the river had been hindered from extending itſelf, would have been

been carried off in proportion as the flood roſe by the increaſed velocity of the ſtream, without augmenting its extraordinary depth perhaps above ſix inches. This great flood then when narrowly examined, and ſuppoſed to be confined all the way between two hills 40 feet aſunder, would probably have turned out to be a ſtream not ſeven feet deep. But the capacity of the Canal I have propoſed, which is 12 by 64, is large enough to let a ſtream four times as great as that paſs eaſily through it, as is well known to thoſe who are acquainted with the motion of fluids, which increaſes as the depth increaſes. Conſequently ſuppoſing a flood twice or thrice as great as the late flood, the Canal and the navigation would have nothing to fear from it.

I enquired the heighth of the greateſt floods in the river Bonie, within two miles of the ſea, where it loſes its name on account of its junction with the more conſiderable river the Carron, and I was ſhewn by one of the overſeers of the works at Carron the marks of the greateſt flood within his remembrance, which are about ſix feet above the uſual ſurface, where the breadth was about ſixty feet. But ſuppoſing the Bonie water (or the Carron) at that time flowed nine feet deep, and ſixty feet broad, the Canal I propoſe could well afford room for a flood twice as great as that. There does not therefore ſeem the leaſt grounds to think that a Canal of the dimenſions above ſpecified would ever be endangered or incommoded by any flood on the ſuppoſition of the waters

waters having a free courſe thro' it. But ſhould it be found that the floods are larger than I have computed them (though the Canal would allow room for floods twice as large as thoſe I have mentioned) 'tis only ſetting the banks 100 feet aſunder inſtead of 80 feet, and the danger is provided againſt; and the Canal becomes more magnificent without any great additional expence, as ſhall be treated of more particularly afterwards.

As to the banks or mounds, it will be proper not to be ſparing in the expence of their firſt conſtruction, but to make them ſufficiently ſtrong, that is to ſay ſufficiently thick, that they may almoſt appear like the work of nature, and never after need any repairs. I would adviſe that they ſhould be raiſed at an average 8 feet above the ſurface of the ground, ſhould be 12 feet broad at top, and ſlope towards the Canal in the proportion of 5 to 3. In the forming of them, the very wideneſs of the Canal gives us particular advantages; for 4 feet depth of earth over the whole bottom of the Channel, together with what is dug for making the back drains, will nearly ſupply earth for the compleating of them. What is wanted may eaſily be carted from different ſpots in the neighbourhood, as is done in the making of turnpike roads; but it will never be neceſſary to bring it from any great diſtance, like the materials of roads, becauſe proper earth may be found almoſt every where. Conſequently the expence of making thoſe mounds may be pretty nearly eſtimated,

eſtimated, from what has been paid for making the turnpike road to Kilſyth per mile, as I reckon that both the banks together would amount to about ſix times as much, deducting however one third for what is already done by nature.

Were the mounds to be conſtructed of the ſize and form above mentioned, I am perſuaded hardly any one would doubt of their being ſufficient for the purpoſe intended by them, of confining the two rivers, and all the water that ſhould come from the point of partition or head ſource, with the other occaſional ſtreams that might fall into the channel in the courſe of the Canal. But to convince the moſt incredulous, I ſhall give an inſtance of a river above 1000 feet broad, navigable even for veſſels of war, which is confined by artificial mounds, and whoſe ſurface is above 10 feet higher than the adjoining ground on both ſides. That river is the Thames, which in different places below London, particularly from the Iſle of Dogs to the Woolwich marſhes, is fenced in on both ſides by artificial mounds, though it be there above 1500 feet broad, and the tide during ſix hours of the four and twenty be full 10 feet above the ſurface of the adjoining ground. Hiſtory I believe does not mention when theſe mounds were firſt made; but probably without them there would be two hours leſs tide at London, and the navigation up and down would be more dangerous, as veſſels might frequently be ſtranded on the ſhallow meadows. Thus though the Thames may juſtly be

be reckoned one of the firſt navigable rivers in Europe, it is nevertheleſs indebted in ſome degree for its navigation to art.

What has been done at the Thames is an example before our eyes of the eaſy practicability of what I propoſe for the preſent navigation. But beſides the Thames, there are numbers of other rivers, and artificial Canals carried above ſoil, without any inconvenience from ſoakage or leakage, or any danger to the banks themſelves, which by their own weight, and the moiſture of the river ſoon conſolidate into one maſs. How many mill-ſtreams might be particularized that are banked on one ſide. The river St. John in Nova Scotia is banked on both ſides like the Thames for a great number of miles. The new river is conducted to London in many places above ſoil. The Duke of Bridgewater's Canal is not only ſupported in many parts by an artificial bank, but the bottom of the Canal itſelf is mounted above the natural ſurface between 30 and 40 feet, and is carried over an artificial mound of earth of that height for ſeveral miles together. To conclude, the Canal propoſed by Mr. Smeaton in both his reports, is intended to be banked in ſeveral places, particularly in a hollow weſt from Camelon, marked D. (ſee the charts in his two reports) 18 feet deep, and 210 feet wide at top, where the very bottom of the Canal for a conſiderable way will run about eight feet above the natural ſurface.

I have hitherto conſidered the Canal as without locks; but having explained the form and ſize of the mounds or banks, and given, I think, inconteſtible proofs that they would effectually anſwer the purpoſe expected from them of keeping up the water on the ſides without leakage, I ſhall now proceed to a particular deſcription of the lock that is intended to keep it up at the end or tranſverſly. I propoſe that the breadth of the Canal ſhould be divided into three ſpaces by two ſtone piers of aſhlar work 10 feet thick and 80 feet long, built parallel to each other at the diſtance of 20 or 24 feet like the piers of a bridge. The ſpace between thoſe two piers forms the lock, by being built up at the upper end ſix feet high, and having flood gates at both ends. I propoſe the fall of the lock to be only ſix feet, becauſe that added to the depth of the water, which may be 11 or 12 feet, will require the lower gates to be 18 feet high, which is a ſize ſufficiently large for the convenience of working; and the tops of the piers may be built flat with a ſmall parapet and a capſtan at each end, for the men to walk upon them to work thoſe gates. If the breadth of the lock be 24 feet, the two outward ſpaces from the piers to the banks on each ſide will be 18 feet wide each; and it is propoſed to ſhut up thoſe ſpaces by flood gates 12 or 13 feet high, made to open occaſionally, and likewiſe to have ſliding vanes or ſluices. Suppoſing the flood gates of all the three ſpaces ſhut, and that there is no want of water at the point of partition or upper ſource, where the chief of the ſupplies

plies will be collected, it is plain that the Canal will quickly be filled to the top of thoſe gates, and the top of the banks; and if the water continues to run, it will ſoon flow over them. But to prevent that, the ſluices of the gates, or the gates themſelves may, by thoſe who reſide at the locks, be eaſily kept open in the proportion neceſſary to give a free iſſue to all the ſuperabundant water, without diminiſhing in the leaſt the quantity once collected in the Canal, by which means what the poet metaphorically ſays of the Thames would be literally true in regard to the Canal, *Tho' never overflowing, it would be always full.*

Let us examine the ſupplies of water at the point of partition or head reſervoir, to ſee if we can draw any more uſe from them than that of filling the Canal, and furniſhing water for the navigation. On the ſuppoſition that the extent of the navigation on the Canal will require annually as by Mr. Smeaton's ſecond report $5333\frac{1}{3}$ lock fulls of water, that, by the lock I have propoſed, will amount to 61,439,616 cube feet per year, or 168,328 cube feet per day. As the Canal of 80 feet breadth has three floodgates at each lock, inſtead of one, I ſhall ſuppoſe that the leakage per day is three times as much as it is ſtated by Mr. Smeaton, or 12 lock-fulls, which is 138,240 cube feet. Reckoning the exhalations in the ſame proportion as Mr. Smeaton, or at one tenth of an inch per day (though that be a large allowance) the daily expence in that article, in a Canal 37 miles

 long,

long, and 75 feet broad at the water line, will be 122,100 cube feet. As the banks I propoſe may juſtly be reckoned as tight as the natural earth, the ſoakage cannot be ſuppoſed more here than in the other Canal, unleſs upon account of the augmented depth; we ſhall therefore ſtate it at 110,000 cube feet per day; and the total expence of water per day will then ſtand thus.

	cube feet
Water expended for lockage per day	168,328
By leakage per day	138,240
By exhalations	122,100
By ſoakage	110,000
Total expences of water per day	538,668

To ſupply this daily conſumption, there are ſix ſmall ſtreams or burns that may be made to empty themſelves into the head reſervoir at the Bog of Dolater, from whence the Canal may be amply furniſhed with water to both its extremities. Theſe burns or ſtreams are computed by Mr. Smeaton to furniſh during ſeven months of the year 1,842,043, cube feet per day; for three other months to ſupply 669,678 cube feet per day, and in great droughts during two months to yield only 254,328 cube feet per day; conſequently though for near two thirds of the year, there would be a great deal more water than is wanted for the navigation, yet during two months it would ſeem that there ſhould be a conſiderable deficiency.

But

But that all deficiencies may moſt certainly and amply be ſupplied, ſo as to afford at all times a great redundancy of water if deſired, will appear moſt plainly from the following further remarks of Mr. Smeaton. The Bog of Dolater, he ſays, to the extent of 200 Engliſh acres, may by dams at each end be laid ſix feet under water, and deducting one foot depth of waſte by exhalations, there would ſtill remain 43,560,000 cube feet of water, which would ſupply the deficiency occaſioned by the drought for 158 days or five months. Beſides at Townhead lint mill, about a mile north from the point of partition, and conſiderably above the level of that, a valley or hollow may by a dam not 50 yards long be laid under water four or five fathom deep, ſo as to form a reſervoir equal in capacity to that of Dolater. On the ſouth ſide of the Canal the waters of Biſhops loch and of four others in the neighbourhood, forming all together a ſurface of between three and 400 acres, may be pent up from four to ſix feet higher than at preſent, and brought to Dolater bog. Beſides theſe three reſervoirs, each of which may contain about 43 millions of cubic feet of water, he mentions ſeveral other rivulets that might be brought to account, and concludes, "That were "ten times as much water neceſſary for the Canal "as what appears to be ſo, there is the evident "means of bringing it and amaſſing it without put-"ting any ſtrain upon nature."

Since

Since then it is ſo eaſy and practicable to have an ample ſupply of water at the point of partition, I would propoſe that proviſion ſhould be made not only for the daily conſumption abovementioned of 538,668 cubic feet of water; but alſo for as much more as ſhould be ſufficient for turning a mill at the firſt lock at each end of the point of partition or head reſervoir. The fall of the lock will ſerve for the fall of the mill; and ſuppoſing a mill at every other lock on each hand all the way downwards, the ſame water that turned the uppermoſt mills would ſerve to turn all the reſt; ſo that if there be 50 locks upon the Canal, there may likewiſe be conſtructed 50 water mills, if wanted, without any prejudice to the navigation. The millers of thoſe mills would be the natural keepers of the locks, and as they would always be on the ſpot, every land flood could be eaſily regulated by them ſo as to be imperceptible in the Canal. Some great floods indeed muſt be excepted; but ſuch as theſe do not happen every winter, and when they do happen, ſeldom continue above ſix or ſeven days, during which time the navigation of the Canal would be rendered only more difficult. This week's loſs however may be ſet againſt the ſame time that would probably be loſt every winter in the artificial Canal by froſt, and the account ſtands balanced; for in froſty winters it may well be preſumed that dead water ſhould be incommoded with ice for more than a week longer than water that has a ſmall current, and which might be made to raiſe and lower its ſurface ſome inches every two or three hours.

When

When we conſider likewiſe that the greateſt floods generally happen in the end of autumn, when the head reſervoirs would be at their loweſt ebb, the rain that deſcends, and the augmented rivulets, might in a great meaſure be kept collected in thoſe reſervoirs, and let gradually into the Canal, by which means the impetuoſity of any flood might be greatly abated. But ſuppoſing the head reſervoirs full, even in that caſe were all the floodgates of the Canal thrown open, there would, as has been ſhewn, be room enough for the greateſt probable flood to paſs off, without ever getting out of the bed of the Canal; for from one dam it would flow to a ſecond, and from that to a third, &c. always finding a channel more capacious than was required.

The locks and dams which I propoſe conſiſting of two piers and three floodgates, beſides rendering the navigation of the rivulets practicable and eaſy, and giving the profit of the mills, might alſo ſerve as bridges by laying beams from one pier to another, and from each pier to the adjoining bank; but it muſt be remembered that the part betwixt the two middle piers muſt be made a draw bridge to be lifted at the paſſing of each veſſel. It is propoſed in general that every dam ſhould ſerve this triple purpoſe, of being a bridge, of lifting the water for the uſe of the navigation, and of containing it for the uſe of the mills.

As the banks I have propoſed will for the greateſt part of the way be above ſoil, and will thereby in-

tercept ſome ſmall rivulets, and occaſional ſtreams, falling from the high grounds on both ſides of the Canal, theſe ſtreams may be made to run in a ſmall trench on the outſide of each bank till they arrive at the firſt lock below them, where they may join the Canal, which is meant to be the reſervoir for all.

Though the dams and locks I have propoſed be ſomewhat different from thoſe commonly uſed, yet if we reflect a little, arguments may be drawn from numberleſs works actually exiſting, and which have ſubſiſted for hundreds of years paſt, in juſtification of their fitneſs and ſolidity. That water may be kept up by floodgates juſt as well as by the old faſhioned method of wiers, I may appeal to all his Majeſty's dock yards, and to numberleſs ſluices both in this and foreign countries. That a ſtone pier ſolidly built in the middle of a current, is able to withſtand its efforts even in the time of a flood, eſpecially a pier 80 feet long, is evident from every well built bridge. Are not bridges built for great floods; and if floods can run below arches, what is to hinder them to run betwixt piers? What is London bridge as it is now repaired but a great lock; and were it required to keep the river Thames always at the ſame heighth above that bridge, I aſk any artiſt, if this might not eaſily be done by floodgates betwixt every pier; or whether by continuing the two piers of the great arch in the middle for 60 feet down the ſtream, and fixing flood gates at each end, I could

could not mount a loaded barge of 200 tons through that arch at the time of the greateſt fall, when the ſurface of the river on one ſide of the bridge is three or four feet lower than on the other?

I have propoſed to form the Canal in the courſe of the rivulets; and if what I have advanced on that ſubject ſhould be found conſiſtent with reaſon and experience, I would adviſe to continue the ſame courſe from the Carron-works to the ſea. I am ſenſible that another Channel has already been judged more proper by the convention of Royal Boroughs. That however was on the ſuppoſition of an artificial Canal not connected with the rivulets. But as the method I propoſe for executing the navigation admits of ſome new reaſoning in regard to this part of the Canal, I hope I ſhall be excuſed for ſubjoining my ideas concerning it. The entry of the artificial Canal at the Heuk with a ſecond entry from the Grange-foot to the Forth, cannot be effected without a great deal of digging; for here, as we are come near the level of the ſea, banking is impracticable. Now for half that digging, and at half that expence, it appears to me that an excellent and direct entry, may be obtained by taking the courſe of the Carron, not winding as it is at preſent, but as it may eaſily be made ſtreight by art. As the ground from the Carron-works to the ſea is a low dead flat, the cutting a direct courſe for the river to the ſea may be eaſily effected ſo that the Canal may communicate with the Forth nearly at right angles,

without leaving one zigzag or winding from its mouth to the Carron-works. When new mouths are cut for it to communicate with the ſea at oblique angles, I ſhould be apprehenſive of the waſhing of the tide for the ruining of thoſe mouths either by deſtroying them, or in time by widening them, or by filling them up. As the water at the Carron-ſhore, which is a mile below the Carron-works, is certainly too ſhallow to allow the Canal to end there, that may be eaſily remedied by advancing the firſt lock farther into the tides way. I would propoſe therefore to build the firſt lock on dry ground in one of the bends of the river ſouth from the houſe of Newton, and after it is finiſhed to let the water in upon it by opening a new channel, which would be the means of cutting off one loop or winding, and of totally annihilating that inconvenient turning at the Heuk. The ground hereabouts being a low flat, all the other loops might in like manner be eaſily aboliſhed; and as in many parts the old channel of the river would ſtill remain, it is evident the digging here would not be a fourth part of the digging neceſſary for making the two artificial entries propoſed by the other plan. Inſtead of more ground being deſtroyed and laid under water, ſome ground by cutting the loops would be gained, which would in part defray the expence of cutting them. The chief objections againſt this entry have been its obliquity and hollowneſs; but by what I have propoſed both thoſe objections would be removed; for on the ſuppoſition of cutting all the loops, it is plain this paſſage

would be as ſtreight as the other ; and by advancing the firſt lock to within three quarters of a mile of the mouth of the river, it may be preſumed there would always be found a ſufficient depth of water for any veſſels that could navigate the Canal. Beſides, the firſt lock by its conſtruction might perhaps afford means of lowering the bar of the river, and deepening its channel from that lock to the ſea; for I would propoſe that the piers which form the firſt lock ſhould be three or four feet higher than the reſt, and the floodgates and ſide banks in the ſame proportion ; ſo that we might have when we pleaſed for a mile above that lock three or four feet more depth of water than was wanted for the navigation. This ſuperfluous water let off about an hour before the turn of the ebb tide would increaſe the current of the water from the lock to the ſea, and in time would probably deepen the channel a foot or two.

Not having viewed the courſe of the Canal from Garſcub-bridge weſtward to the junction with the Clyde, I ſhall only obſerve that from the charts in both Mr. Smeaton's reports it would appear that the navigation may be effected in great part by banking either by the Alander-paſſage or by the Canys-burn paſſage. As to the extra expences in cutting the hill in the Alander-paſſage, and the hill at the Weaver's houſe above Graſcaddon, with other charges that the courſe of the Canal in this part renders neceſſary, I ſhall transfer them as they ſtand in Mr. Smeaton's eſtimate, though my me-

thod would rather tend to reduce them than augment them, and would render ſome of them unneceſſary.

Having endeavoured to ſhew, that the method I propoſe of banks and locks, is ſo far from being a novelty, that it has been practiſed time out of mind in Great Britain (for what is the Canal by banks as I propoſe it but a continuation of gather-dams; and my locks what elſe are they but ſo many bridges of three arches each) I ſhall proceed to conſider two objections that may be made to this method; and ſhall conclude with giving an eſtimate of the probable expence of executing a Canal according to it.

As I propoſe the lowermoſt part of the valley for the courſe of the Canal, and that it ſhould be the common reſervoir of all the water ever likely to flow in that valley, it may be objected that it might in time fill up by ſand and mud waſhed into it by rivulets in their deſcent. But it ought to be remarked, that the ſix rivulets that are propoſed as the chief ſupplies of the navigation, and are now the ſources of the Bonie-water and the Kelvin, are intended by my plan as well as by Mr. Smeaton's, never to empty themſelves into the Canal, but to empty themſelves into the grand reſervoir at the bog of Dolater or the point of partition, conſequently they can have no greater inconvenience by my plan, than by Mr. Smeaton's. It may be ſaid however, that in the courſe of the Canal there are ſeveral other rivulets that by my plan muſt fall into it at different places.

places I anſwer, true. But theſe rivulets are ſo very inconſiderable, that Mr. Smeaton propoſes they ſhould paſs under his Canal through tunnels, which is a plain proof that he was never apprehenſive of their becoming impetuous torrents. Nature indeed, that has been ſo favourable in the diſpoſition of the ground for forming this Canal, ſeems no leſs favourable in regard to the ſupplies of water; for though they promiſe to be plentiful, yet they have not the appearance of ever overpowering. Small rivulets that run upon a declivity, and are apt to become torrents, never ſwell immoderately but at the expence of the ground through which they flow, and in length of time form deep gullies which ſhew in ſummer, what they themſelves have been in winter. But where there is no ſuch appearance, 'tis a ſtrong preſumption that the rivulets are hardly ever very impetuous. The rivulets that I obſerved in this valley have none of them cut to themſelves deep tracts, conſequently they cannot be ſuppoſed to waſh much earth in their courſe, and therefore we need be under no apprehenſion that in emptying themſelves into the grand reſervoir at the bog of Dolater they will fill it up with ſand or mud. The rivulets here when in an augmented ſtate, no doubt are muddy as all other rivulets are. But let us examine whether the form of a Canal which I propoſe, would be more liable to be filled up with mud than any other. I propoſe a free courſe in my Canal for all the water ever likely to flow into it; and that the ſuperabundant water ſhould be let off by ſluices at the

the bottom of each ſide floodgate. This ſuperabundant water will perhaps for four or five weeks in a year run muddy; but as it is propoſed to let it off at the bottom, the Canal will have a bottom current, which added to the depth of water, will occaſion a conſiderable flow in the manner of a ſuction at the bottom of the ſtream, and thereby prevent the mud from depoſing and ſettling in this kind of a Canal more than in a Canal where the ſuperabundant water is to flow at the top over dams and wiers placed in the bank. We have a proof of this in thoſe pieces of water that have a ſluice in the middle of the dam that collects them; for directly oppoſite to this ſluice, the channel always keeps itſelf clear and hollow, however it may fill up at the ſides, where the water has no direct iſſue. But after all, ſhould ſome mud be depoſed in the Canal, the channel may be cleared every two or three years at a very ſmall expence, either by taking it up by machines in barges as ballaſt is taken from the bottom of rivers, or by tearing it up by hooked irons all along the bottom, leaving the bottom current to carry it off.

It may likewiſe be ſaid, that as I propoſe a free courſe in my Canal for all the water ever likely to run into it, there will therefore be a ſenſible current in the Canal, which will in ſome degree impede the navigation, and retard veſſels in their paſſage. But if it be remembered how much water is ever likely to flow in the Canal; and if we recollect the capacity of

of the Canal and the conſtruction of the locks, this objection will entirely vaniſh. The amount of the ſupplies at the point of partition, taken at an average the whole year round, will be about one million of cubic feet per day, which is 500,000 cubic feet running one way, and 500,000, running the other. Now ſuppoſing the locks ſtanding at a medium half a mile diſtant one from another, the water contained in the Canal between any two locks, will then be 1,638,560 cubic feet; but that is more than three times the daily conſumption, conſequently ſuppoſing that part of the Canal were to receive no ſupplies, it would take no leſs than three days to empty itſelf, which plainly ſhews that the current in the Canal would be no wiſe diſcernible except at the fall of the lock. How many mill-ponds or rivers dammed up for the ſake of mills appear totally ſtagnant, yet upon examining the lapſe of water running off to the mill and running over the dam, theſe two together will be found to be twice as much as what would flow in the Canal even in common rainy ſeaſons. It is propoſed at all times to keep the ſurface of the Canal from lock to lock upon a dead level, (the time of a great flood excepted) conſequently the ſuperabundant water would ſeek its way by the bottom and would paſs off by the floodgates, where its courſe would not even be very diſcernible, as the bottom of the ſtream in the upper dam would be four or five feet below the ſurface of the ſtream in the lower dam; ſo that the Canal would in effect be like ſo much ſtagnant water, though at the ſame

time

time one million of cubic feet ſhould daily have a free iſſue through it towards each extremity. If nevertheleſs, the draught from the ſea to the point of partition, ſhould be very little ſtiffer than if the water were totally ſtagnant, it will in return be proportionally eaſier from the point of partition to the ſea; which two circumſtances will very nearly counterbalance each other, ſo that the time employed in paſſing this Canal will be much the ſame as what would be required to paſs a Canal totally ſtagnant, ſuppoſing the number and the ſize of the locks in both equal.

Having explained in general every requiſite for the conſtruction of the Canal according to the new method propoſed, I ſhall proceed to give an eſtimate of the probable expence of compleating it according to that method.

The length of the Canal will be about 37 miles from the mouth of the Carron to below Dunbuck ford on the river Clyde, with a ſide branch to Glaſgow as in the charts already printed; and its breadth from the outſide of one back drain to the outſide of another 129 feet or 43 yards; conſequently it will occupy in the whole 452 Scotch acres. But it muſt be remembered that great part of this tract is waſte ground on both ſides of the rivulets, and inſtead of being of any profit to the owners, often brings damage to them, conſequently

conſequently the parting with it would render what remains of more value to them. The real ground to be valued for the Canal would therefore probably not exceed 300 acres, which at 20 *l.* per acre is £. 6,000

Suppoſing 100 acres more allowed for reſervoirs, that at 20 *l.* per acre is 2,000

In the length of the Canal there will be about four miles required to be dug wholly within ſoil; namely two miles at the point of partition, and one mile at each end next the ſea. This makes about 600,737 cubic yards of digging, which at 3 *d.* per cubic yard is - 7,509

N. B. If I rightly remember, 2 *d.* ½ is the uſual price of digging the cubic yard of ſoil for the navigations in Ireland, where wages are much on the ſame footing as in Scotland.

I propoſe the banks at an average eight feet above ſoil, 12 feet broad at top, and ſloping towards the Canal in the proportion of five to three, which will give for a medium thickneſs 18 feet and a half. Both the banks together being reckoned 68 miles long, the cubic yards contained in them will amount to 1,968,071, which

To be carried forward 15,509

Brought over	£.	15,509
at 3*d.* a cubic yard is 24,600 *l.* But of this ſum, as I have above obſerved, one third ought to be deducted for what is already done by nature, conſequently there will remain for the expence of banking, -		16,400
N. B. As the inequality of the ground will render it very difficult to meaſure the banking, when done by the piece, it would be adviſeable to do it by days wages, which will probably bring it cheaper; for a labourer at 6*d.* or 8*d.* per day, may be expected to dig at a medium three cubic yards.		
Fifty locks at 1000 *l.* each, are		50,000
Two abutments on the banks at each lock, in all an hundred		10,000
For dams at the ends of the bog of Dolater, as by Mr. Smeaton's eſtimate		2,277
To extra expences on the Alandar paſſage by the ſame eſtimate,		13,754
To extra expences in carrying the Canal to Glaſgow, over the river Kelvin, by Mr. Smeaton's eſtimate,		5,333
For conducting ſtreams to the reſervoir, by the ſame eſtimate -		500
To be carried forward		113,773

Brought forward	£. 113,773
For 100 ſmall bridges of one arch, 10 feet ſpan each, - -	3,000
For building 80 mills, -	5,000
For advancing the Canal from Dalmuirburn foot, to below Dunbuck ford, as by Mr. Smeaton's eſtimate,	18,000
For unforeſeen charges,	20,000
Total expence	159,773

I have already mentioned, that were the Canal to be 100 feet broad inſtead of 80 feet, the additional expence would not be very conſiderable, provided the method of banking be purſued; for 'tis plain the ſame banks that would contain the water in a Canal 80 feet broad, would alſo contain the water in a Canal 100 or 300 feet broad, conſequently the additional charge would be chiefly upon the purchaſe of the land, and the conſtruction of the locks. The Canal of 100 feet breadth exceeding the former by 20 feet, would conſequently occupy in a length of 37 miles, 71 acres more than the other, which at 20*l.* an acre would be 1420*l.* The locks and dams in this Canal might be built with four piers inſtead of two, which would probably enhance the expence 20,000*l.* and ſuppoſing the two middle piers to ſtand as before, at 24 feet diſtance, the two outward piers may be placed ſo as to leave two ſpaces 16 feet broad each, betwixt them and the

middle piers, one of which ſpaces may be formed into a ſmall lock for ſmall veſſels. Allowing 20,000 *l.* more for extra expences, the whole additional charge incurred in forming the Canal 100 feet broad by banking, would be 41,420 *l.*

By purſuing the method of banking, I venture to aver, that a Canal of 15 feet deep, and 300 feet broad, excepting at the locks, might here be made from ſea to ſea, for the expence of Mr. Smeaton's higheſt eſtimate, or 293,444 *l.* which he computes a Canal will coſt, 67 feet broad and 12 feet deep dug all under ſoil. Every reader may recollect, what great quantities of water he has ſeen collected in gather-dams, or mill-ponds, by banks above the ſurface; and I appeal to any artiſt who ſhall view this vale, whether it is not here very eaſy to form a ſtring or chain of gather-dams from ſea to ſea, affording a depth and breadth of water ſufficient for the navigation of veſſels of one or 200 tons. Some Canals in this iſland are juſtly matter of wonder, on account of the curious artifices uſed in their conſtruction; but I could wiſh the whole wonder of this Canal ſhould be its ſimplicity, joined to an air of magnificence.

APPENDIX.

THE preceding reflections have been chiefly confined to the Navigation betwixt the Forth and Clyde; but the method explained by them may likewiſe be applied to almoſt every rivulet and river not navigable; and if put in practice in Great Britain and Ireland, would give us, at a very eaſy charge, above 5000 miles of inland Navigations, and perhaps above 1000 water-mills, if wanted. This computation may appear at firſt view exaggerated; but let us only reflect upon the great numbers of rivulets and rivers in the two kingdoms, and taking them from their ſource, allow but a length of 20 miles to each capable of being made navigable, and we ſhall quickly be convinced, that the computation above-mentioned is under the truth. By the new method, theſe 5000 miles of inland Navigations may be compleated at very little more expence than what would be required for making the ſame number of miles of turnpike; and certainly the benefit ariſing from the former, would greatly ſurpaſs what could be expected from the latter.

Having no where ſeen an eſtimation of the advantages which a State gains, or may gain from inland Navigations, I ſhall here ſubjoin a few reflections on that ſubject, which, with many other eſſential principles of political arithmetic, are far from being ſo generally underſtood as they deſerve. As all

all Canals may be conſidered as ſo many made roads, where one horſe will draw as much as 30 horſes do on the ordinary turnpikes, or where one man alone, without any horſes, will tranſport as many goods as three men and 18 horſes uſually do on the common roads, the public would be great gainers, were they to ſpend upon the making of every mile of a Canal, 20 times as much as they ſpend upon making a mile of turnpike; but here a method has been explained, by which the mile of a Canal may often be made at a leſs expence than the mile of a turnpike; conſequently they have a double inducement to undertake thoſe navigable communications.

Bad roads, and difficult communications between places remote from each other, add a kind of ſterility to a country, and render moſt things much dearer and ſcarcer than they would otherwiſe be. And a nation, placed in a moſt fertile ſoil, and moſt favourable climate, with bad roads and no carriages, will not be ſo rich and affluent as another nation leſs favoured in climate and ſoil, who have excellent roads, and numbers of wheel-carriages, ſuppoſing the genius and induſtry of both nations to be the ſame. When the Europeans firſt entered America, the Peruvians, who were to a certain degree a civilized nation, had no other methods of tranſporting goods and heavy materials but on porters ſhoulders, or by the force of mens arms; and it has been ſuppoſed that 2000 of them have been employed in removing one ſtone. What a wide diſtance from them to the Dutch, who by the means of five or ſix

ſailors

ſailors remove ſtones 20 feet long from the quarries of Great Britain; and whoſe cities, towns and villages have ſuch a free communication with each other by water, that they ſeem like the ſtreets of the ſame city in reſpect to the convenience of carriage. I know a certain wood in Great Britain, which has the advantage of a ſaw-mill; but being ſituated in the midſt of mountains, where there are hardly any roads, it is the work of one horſe to drag away four ſmall deal boards, which, if the diſtance on one ſide exceed 12 miles, come dearer than if they were brought thither from Norway. The great difficulty and expenſiveneſs of land-carriage likewiſe obliges the Spaniards and French to draw from Sweden and Dantzick, great part of the timber for their dock-yards, though they have in their own foreſts immenſe numbers of excellent trees, that would more than ſuffice for all the purpoſes of ſhipping. Many cities, ſituated upon navigable rivers, are not ſo much indebted for their wealth and proſperity to the foreign trade which they carry on, as to the eaſe and convenience with which they are ſupplied with almoſt every article of conſumption; for, ſuppoſing all the inhabitants that have no dependance upon foreign trade, were tranſplanted from one of thoſe cities to a fertile ſpot in the midſt of mountains ſomewhat inacceſſible, they would quickly, with their uſual induſtry and revenues, find themſelves involved in ſtraits and difficulties, and their numbers would decline daily on account of the dearneſs of living.

Bad roads do not only tend to render things dearer, but alſo ſcarcer; for before the eſtabliſhment of the poſt-office, (which may be compared to an open road of the eaſieſt communication) the carriage of a ſingle letter was not only extremely dear, but very few letters were written. The people might live eaſily, were the number of letters diminiſhed two-thirds; they could not however be ſaid to live affluently, were the number of neceſſaries diminiſhed two-thirds. The badneſs of roads lengthens the time of the tranſportation of goods; for the ſame waggon that, upon an open and plain road, would be a weekly waggon, upon a rugged and difficult road becomes a monthly waggon; but the carrier, inſtead of increaſing the number of his waggons, and employing four inſtead of one, contents himſelf with quadrupling the price, by which means the goods become both dearer and ſcarcer; and a nation, in a fertile ſoil, and with great numbers of people, is far from being lodged, cloathed, or fed ſo well as might be expected.

The tranſportation of goods and heavy materials, in ſome caſes, amounts to more than their prime coſt; often it is only a fourth or a ſixth of their value, and ſometimes perhaps not an hundredth part; but in general, the carriage of goods from one place to another, may be reckoned a twentieth part of their value. The annual conſumption of the people of Great Britain may be computed at 100 millions, and of the inhabitants of Ireland at 15 millions *.

* I may, perhaps, on ſome future occaſion, explain the reaſon why I have fixed on thoſe two ſums.

As full three-fourths of what people uſe may be ſuppoſed to be brought from a diſtance, the carriage for Great Britain will then be 3,750,000 *l.* or 5 *per cent.* of 75 millions, and for Ireland 562,500 *l.* One half of that carriage is perhaps at preſent performed by water to the beſt advantage; conſequently for land-carriage, there can only be counted in Great Britain 1,875,000 *l.* and in Ireland 281,250 *l.* But were all thoſe inland Navigations executed, which the new method renders practicable, two-thirds of what is ſtill carried by land, might be tranſported by water; and ſuppoſing the expence of carriage by water to be a fifth of that by land, thoſe two-thirds which now coſt Great Britain 1,350,000 *l.* and Ireland 187,500 *l.* would then only coſt to the firſt 270,000 *l.* and to the ſecond 37,500 *l.*; conſequently there would be a compleat annual ſaving to Great Britain of 1,080,000 *l.* and to Ireland of 150,000 *l.* But that is not all the advantage the two kingdoms would reap from the propoſed enlargement of water-carriage; for the men and horſes that are now maintained by the two ſums above mentioned unprofitably to their reſpective nations, would at leaſt gain as much in a profitable manner, either by the labours of huſbandry, or otherwiſe. The clear annual profit would then be the ſaving on one hand, and the augmentation of induſtry on the other; which two ſums, when added together, would make for Great Britain 2,160,000 *l.* and for Ireland 300,000 *l.* But if the price of carriage in general may be computed at 10 *per cent.* inſtead of

20 *per cent.* which is the opinion of many judicious people, in that caſe Great Britain would gain annually 4,320,000 *l.* and Ireland 600,000 *l.*

People begin of late to be ſenſible of the advantages of turnpikes, and acknowledge that the repairing of a road, or the making of a turnpike, often gives a new face to a whole country, and introduces plenty and abundance in places that were before uncultivated and unprofitable. A Navigable Canal might be expected ſtill to augment thoſe advantages, eſpecially as the expence of making it by the new method would not, in many caſes, be ſo conſiderable as the expence of making a turnpike. How many rivers are there, which, at a very ſmall charge, may be made navigable; but at preſent, being occupied by mills during their whole courſe, the inhabitants, who earneſtly deſire a Navigation, have hitherto deſpaired of effecting it on account of thoſe mills. By the new method this obſtruction is entirely removed; for, were thoſe rivers to be made navigable in the manner above deſcribed, the number of mills, inſtead of being diminiſhed, might be augmented, and the mills themſelves rendered more profitable to their owners, and to the public. The dams and locks might indeed occaſion the ſituation of ſeveral of them to be changed, and place them half a mile higher up, or half a mile lower down the ſtream; but if that would be a detriment to ſome few, it would alſo be an advantage to others, by drawing them nearer ſome bridge or croſſing road; conſequently the benefit on one hand, might

be reckoned fully to counterbalance the loſs on the other.

When a river has, for a conſtancy, three feet depth, and is without falls, ſteep currents, or ſhallows, it may be counted naturally navigable; but as the laſt circumſtances ſeldom all concur, even in rivers that have a greater depth than that above mentioned, we ought to have recourſe to art to r duce the river to ſo many different levels, and at the ſame time deepen the water, by raiſing it by dams and mounds of the faſhion above deſcribed. I know a conſiderable river which engineers have attempted to render navigable by digging away the ſhoals and fords; but that has not only been a great expence, but an uſeleſs one; for the river being left to have the ſame rapidity as before, formed new ſhoals upon the firſt great flood, and now the inhabitants having ſeveral times loſt their labour, raſhly conclude, that it is impoſſible to make their river navigable. To deepen a river is not the only thing neceſſary in order to procure a Navigation; it is no leſs eſſential to break its currents, and to guard againſt the bad effects of floods. As the new method I propoſe not only ſecures thoſe three material points, but alſo gives us a fourth, in enabling us to change a ſmall rivulet of a foot of water into a conſiderable Canal, I ſhall now proceed more particularly to explain its different branches, by the execution of which, almoſt any ſtream whatever may be rendered navigable. It is firſt of all neceſſary to examine how much water the ſtream may contain

in mean ſeaſons, which may be done by taking its breadth and depth at fords, which allow all the water to paſs with its uſual current. Next, it is proper to conſult the oldeſt perſons living in the neighbourhood, to be informed of the greateſt floods that have happened to it in their memory. The heighth of thoſe floods is to direct as to the heighth of the mounds, and the width of ſpace betwixt them, which two laſt numbers multiplied into each other, ought to make a ſum larger than that produced by the multiplication of the heighth of the greateſt flood, into once and an half the uſual breadth of the river. For example, if the uſual breadth of the river be 20 feet, and the greateſt heighth of the flood 7 feet, the two numbers to be multiplied into each other, to regulate the quantity of water between the mounds are 30 and 7, and ſo of moſt others. It muſt be remembered, however, that it is much ſafer to place the mounds wide than to raiſe them high, as it is chiefly the depth that renders water dangerous and unmanageable. For inſtance, though 5 times 50, and 8 times 31, give nearly the ſame product; yet the firſt two numbers ought to be preferred for depth and breadth, to the laſt two numbers; becauſe, when the water is ſpread out broad, the mounds are in ſecurity, and five feet is a depth ſufficient for the barges that ought to navigate ſuch a Canal.

When a ſtream to be made navigable by art, runs through any city or town, it will be always proper to contrive, if poſſible, to place the dam and lock

lock at the lower end of the town, where the rive quits it, by which means the fall of five or ſix feet at the back of the dam will ſerve for a drain to the place; the mounds, which may there be made twice as broad as uſual, will ſerve for quays or wharfs; the town, if on a flat, may by degrees be raiſed ſix or eight feet, which will add to its healthfulneſs; and the carriage backwards and forwards to the mills at the dam will be ſhort and inconſiderable. By the new conſtruction, the rivers would have no declivity any where but at the dams, and as the mounds are propoſed to contain the greateſt floods, the country would be no longer expoſed to their ravages; and a very little attention might ſecure each fall againſt the force of the ſtream to which it would be oppoſed. Though a ſtream, with two or three feet fall, will eaſily undermine a looſe crumbly ſoil, or a perpendicular bank, and make great ravages year after year in the adjoining fields and meadows, yet the caſe is altogether different when a floor is prepared for it, or when it is bounded on both ſides by ſtrong piers, and falls upon a firm pavement compoſed of large ſtones, well rammed or ſtrongly cemented. For a proof of this, I need only appeal to the maſon-work or wooden-work of an infinite number of mills, where the ſide-fall is much ſtronger than what the direct fall of the propoſed dams would be, as the ſurface of the lower ſtream would be higher than the bottom of the upper, or nearly as high.

As the ſurface of many rivers, in their ordinary ſtate, lies a foot or two feet within ſoil, that is below

low the ſurface of their banks, the mounds might often be made at a very trifling expence, and would not riſe above a foot or two higher than the ground on which they ſtand; but if a river is ſerpentine, it will be proper in forming the mounds, to run them farther from the banks, ſometimes on one ſide, and ſometimes on another, in order to leſſen its obliquities and turnings, and reduce it as near a ſtrait line as poſſible. When a river runs through a large plain or meadow, where the inundations, inſtead of being detrimental, would be beneficial, there the Canal might be much narrower; but the ſuperfluous water, in this caſe, muſt not be ſuffered to run over at the mounds; but at the diſtance of an hundred feet below each fall, where the natural ground becomes the bank, a hollow or ſmall trench may be made on each ſide to let the water eſcape, after it arrives at a certain heighth.

In many ſmall rivers, it is not uncommon to ſee a mill-ſtream cut for a mile together upon a level, at a conſiderable expence, for the ſake of one mill, while the overplus water is ſuffered to run in the old channel, or ſeek out different channels for itſelf, which are often very ſerpentine, and thereby lay waſte conſiderable tracts of ground, though ſome of them have not perhaps a depth of four inches of water, and others of them are quite dry during the ſummer months. To one acre which the mill-ſtream occupied, I have often ſeen the overplus water occupying or ravaging four. The common notion I know is, that there is a neceſſity for following this method,

method, in order to make room for the ſuperabundant water in time of great floods, which were it to enter the mill-ſtream, and bear down upon the mill, would overturn and deſtroy every thing. But by the method I propoſe, all thoſe different channels may, without any danger, be reduced to one, which would not cover above half the ground, and not only be doubly uſeful as a mill-ſtream, but alſo ſerve as a Navigable Canal, by adding a depth of two or three feet to the ſtream, and opening a communication between the water of the upper dam, and that of the lower. As it is altogether equal, in regard to the force of the fall, whether the ſuperfluous water run off at the ſide or the end; the dam at the mills may therefore be made in the new manner propoſed, with a lock in the middle; and at the ſame time, at a very ſmall charge, the mill-ſtream may be made twice or thrice as wide as before, and lifted two or three feet, by forming mounds of that heighth on both ſides of the earth dug from the banks. If there was water enough for one mill before, there would now probably, by this new arrangement, be water ſufficient for two mills; the country would be ſecured from the ravages of a flood; ſome ground would be gained that was before occupied by the ſuperfluous water; and the landſkip would be ornamented with a regular Canal flowing in a gentle current, and ſerving for the carriage of goods and heavy materials. Were this Navigation but to extend ten miles, it might nevertheleſs be extremely beneficial to the neighbourhood, if any coal-pits or quarries of lime or free-ſtone were ſituated near the banks;

banks; but if it extends ten miles, it may alſo be made to extend 200 miles: for, upon the principles of the new method propoſed, the moſt inland ſource and rivulet, from the place where it is ſtrong enough to turn a common mill, may be made to communicate with the ſea as a Navigable Canal, if there be no obſtruction from precipices or cataracts.

To conclude, were we to make the ſuppoſition of two ſtates, the one having all its cities, towns, and villages upon navigable rivers that had an eaſy communication with each other, and the other placed in a mountainous country, where the roads are broken and difficult, and that both ſtates were equal as to ſoil, climate, induſtry, and defence againſt foreign enemies, commodities and manufactures in the former ſtate might be expected 30 *per cent.* cheaper than in the latter; or in other words, the firſt ſtate would be a third richer and more affluent than the ſecond. This perhaps is one of the chief cauſes of the great wealth of China, which hiſtorians tell us is wholly interſected with navigable rivers and Canals; but by the new method propoſed, Great Britain and Ireland might ſoon rival China in this laſt particular, and conſequently their people in general might be more rich and affluent, and their force, when united againſt a foreign enemy, be greater and more formidable.

THE END.